

# **Internal Waves on the Continental Margin**

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## **LONG-TERM GOAL**

To describe and understand the changes that occur in internal waves as they evolve and propagate shoreward over the shelf break into shallow, near-shore waters.

## **OBJECTIVES**

To carry out fieldwork and to analyze the resulting data for a description of the fields of temperature and of vertical and horizontal velocity in shoaling internal waves with much finer spatial resolution and longer duration than previous descriptions; to use this description to estimate the relative importance of dissipation, wave dispersion, shoaling depth and various types of nonlinearity in shoaling internal waves; to construct a dynamically informed model of the observed wave field suitable for carrying offshore observations to stations nearer the shore and for studying wave induced secondary flows and particle paths. This work will constitute the Ph.D. thesis of graduate student Jim Lerczak.

## **APPROACH**

Internal wave “antennas” composed of moored Acoustic Doppler Current Profilers (ADCPs) generally covering the middle 75% of the water column plus one to seven continuously recording temperature loggers distributed along the mooring line were deployed in waters just offshore of San Diego at depths ranging from 15 m to 500 m during the summer and fall of 1996 and 1997. Simultaneous meteorological observations are available from Scripps Pier in La Jolla. CTD yo-yo’s were carried out over periods ranging from about 3 to 24 hours during mooring deployment, service and recovery, and a bottom pressure sensor was deployed at the 15 m mooring. The instruments were removed from the water early in FY98.

## **WORK COMPLETED**

All ADCP and temperature logger time series, as well as the pressure sensor series have been processed into a form suitable for analysis. Basic statistical analyses (e.g. spectra, empirical orthogonal function representations of variously band-passed data) have been constructed. Construction of a web site describing the experiment and data (<http://www-ccs.ucsd.edu/iwaves>) has begun.

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## RESULTS

Mode one internal waves explain approximately 80% of the high-frequency (buoyancy frequency to 1 cph) variance in shallow water (15 to 30 m). The critical internal wave frequency for the nearshore region of the continental slope is approximately 7 hours, so that the high-frequency waves are very subcritical. The internal wave field is dominated by onshore propagating undular bores and solitary-like events, in addition to apparently independent near-buoyancy frequency motions. Wave packets generally arrive at the nearshore study site on a semi-diurnal schedule. Long-wave phase speeds decrease from approximately 25 cm/s to 12 cm/s as the waves propagate from a water depth of 30 m to 15 m. The dissipation time scale is approximately 2 hours, so that the waves decay significantly over the time (approximately 3 hours) it takes them to cross the nearshore array ( $\Delta x = 1.5$  km). A simple dissipative linear model cannot carry 30 m data to the 15 m mooring. Consequently, non-linearities appear to be important. There is little or no correlation in the high-frequency band between the 70 m and 100 m records with the 15 to 30 m records.

## IMPACT/APPLICATION

The data provide a new degree of vertical and horizontal resolution of the velocity and temperature fields associated with internal borelike and apparently solitary disturbances in shallow (tens of m) water during summertime and early fall. Vertical velocities are clearly *not* significantly contaminated by instrument tilt and/or bottom slope effects. These data will allow new detail in delineating the realistic range of parameter space associated with weakly nonlinear dynamical models of shoaling, dissipative internal disturbances. The resulting dynamically informed description of the shoaling internal wave field will be useful both for nearshore acoustic studies and for nearshore biological studies. The studies will also provide insight into the role of internal waves in the mixing of the nearshore region of the continental shelf and the significance of internal wave generated secondary currents in the nearshore circulation.

## RELATED PROJECTS

Dr. Peter Franks (SIO) and Ms. Cleridy Lennert are studying internal wave-induced changes in the concentration of planktonic organisms as well as the importance of large-amplitude, nonlinear internal waves to the cross-shelf transport of these organisms. The data from our nearshore ADCPs has been very useful for their research.

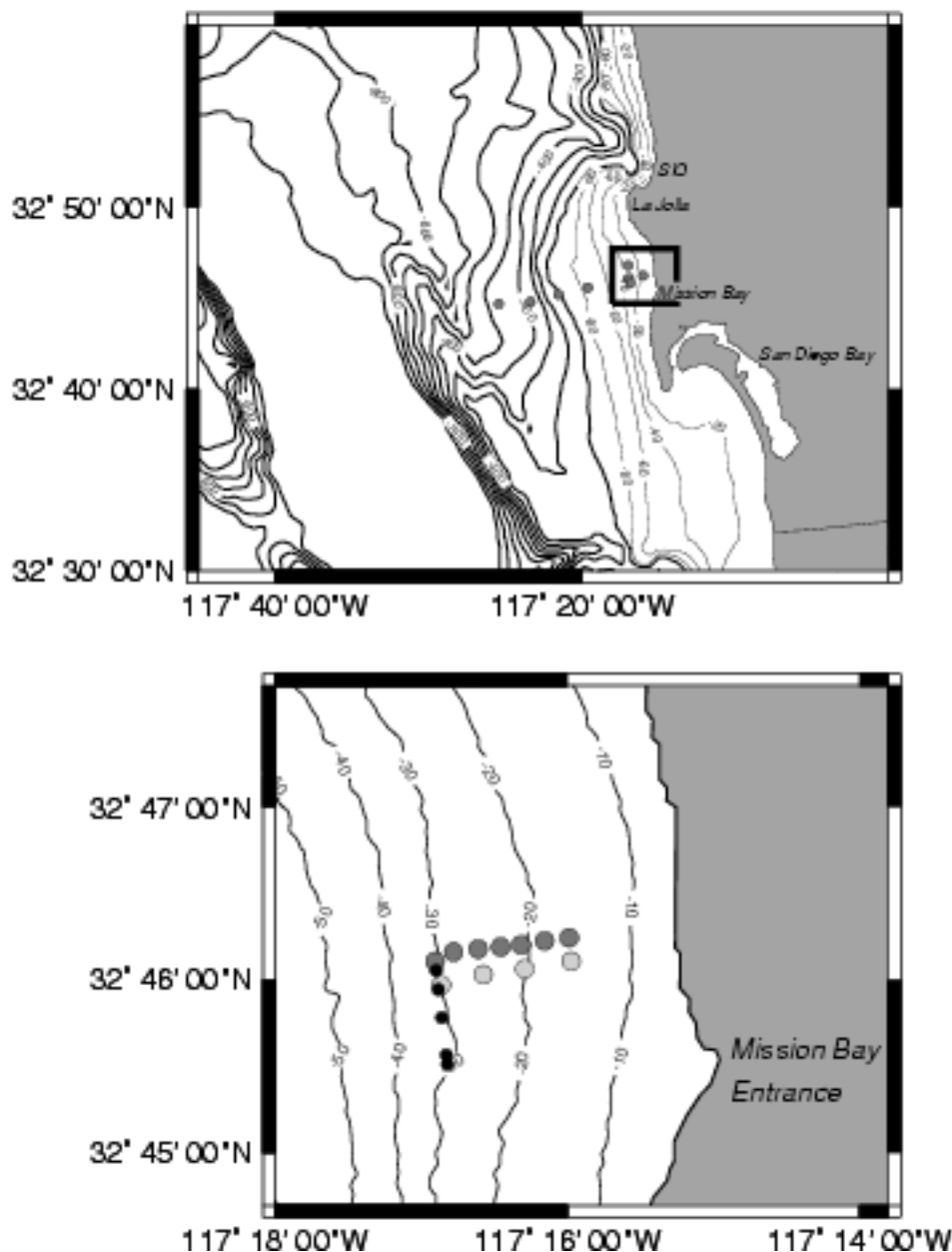
## PUBLICATIONS

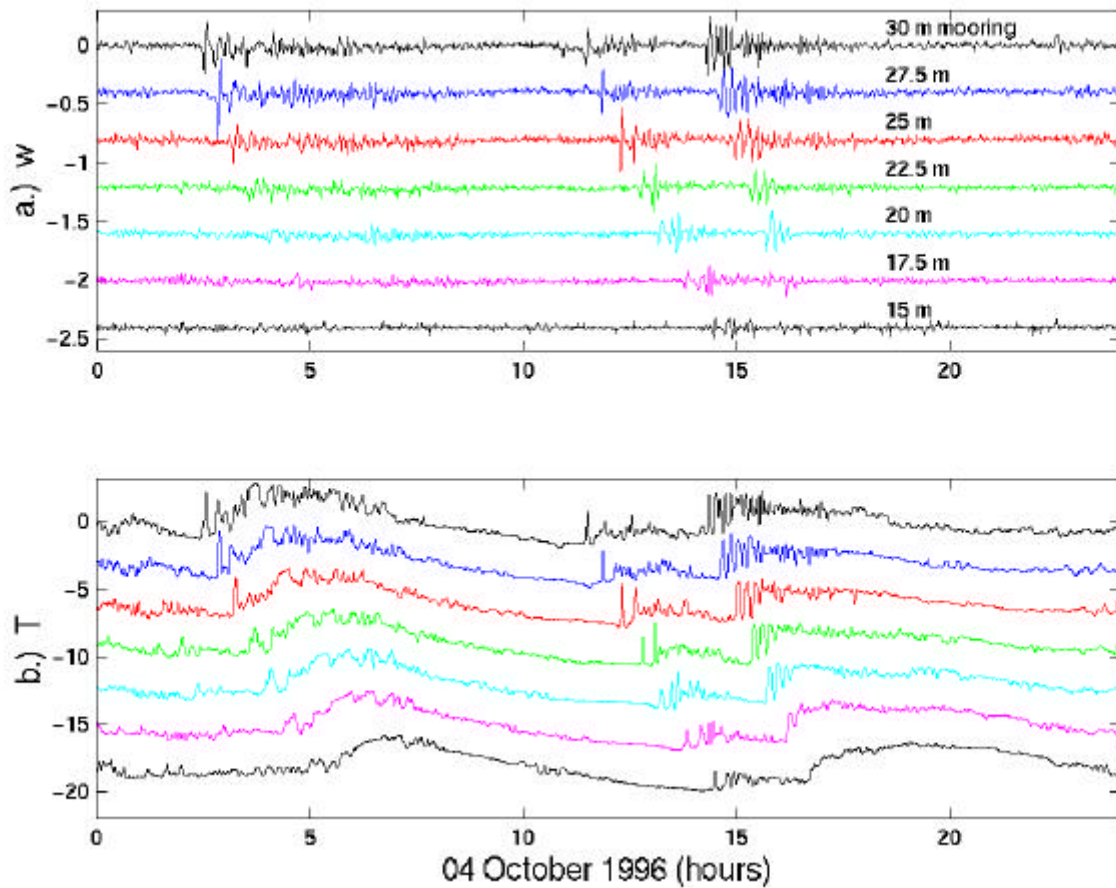
Lerczak, J.A., M.C. Hendershott, and C.S. Winant. 1998. Observations of high-frequency internal waves off of Mission Beach, CA. Presented at the Ocean Sciences Meeting. 9-13 February, San Diego, CA.

Lerczak, J.A., C.D. Winant, and M.C. Hendershott. 1998. Linear analysis of high-frequency internal waves in shallow water. Presented at the Eastern Pacific Oceanography Conference. 23-26 September, Mt. Hood, OR.

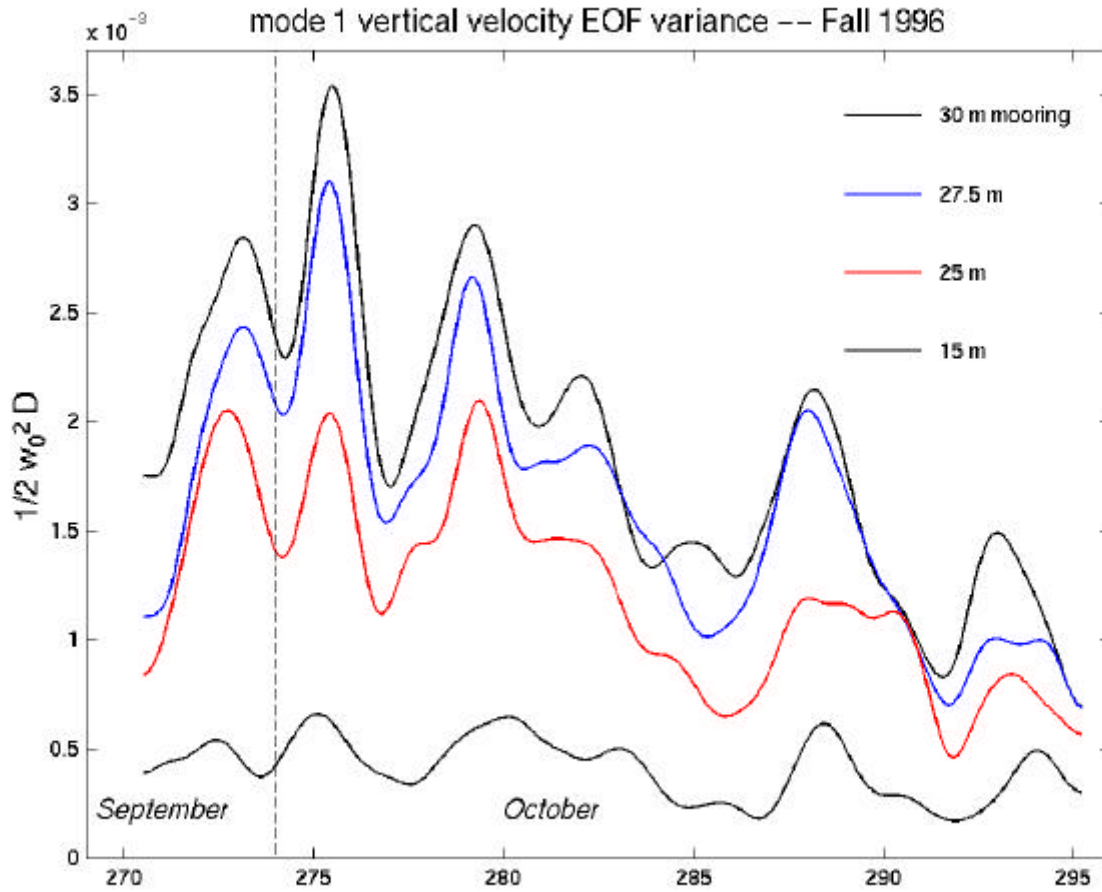
Lerczak, J.A., C.D. Winant, and M.C. Hendershott. 1998. A study of dissipative, shoaling high-frequency internal waves in shallow water. Presented at the Internal Solitary Wave Workshop. 27-29 October. Sidney, B.C., Canada.

**Figure 1. Top: Map of the 1996/97 Internal Waves on the Continental Margin experiments off Mission Beach, CA. The large circles indicate the locations of moorings which were equipped with Acoustic Doppler Current Profilers (ADCPs) which measured the three current components as function of time and depth and temperature loggers (TLs) secured to the mooring line which measured temperature fluctuations at fixed depths as a function of time. Bottom: Various array configurations used in the study of the internal wave field in nearshore region of the continental shelf. The large circles indicate locations of moorings which were equipped with a bottom-mounted, upward-looking ADCP, and four TLs evenly spaced in the water column. Single, mid-column TLs (indicated by the solid, black circles) were deployed along the 30 m isobath for a period of about one month during the summer of 1997.**





**Figure 2. a) Mode one EOF amplitude time series of vertical velocity calculated for each of the seven nearshore moorings deployed in the fall of 1996. b) Mode one EOF amplitude time series of temperature fluctuations calculated for each of the seven nearshore moorings deployed in the fall of 1996.**



**Figure 3. Mode one EOF variance of vertical velocity versus time for four of the seven nearshore moorings deployed during the fall of 1996. The data was divided into 33 h blocks, and the EOFs were calculated at each mooring for each of these blocks. The time series shows how the variance (smoothed over 33 h) varies over time. The variance is scaled to give an estimate of the vertically integrated vertical kinetic energy ( $\frac{1}{2} \times w_0^2 \times D$ , where  $w_0$  is the variance at the depth of maximum variance and  $D$  is the water depth). The time series are clearly correlated and the variance decays monotonically from the 30 m mooring to the 15 m mooring.**